PATENT SPECIFICATION

DRAWINGS ATTACHED

1,156,369

1,156,369

Date of Application and filing Complete Specification: 6 March, 1967.

No. 10444/67.

Application made in United States of America (No. 541,331) on 8 April, 1966.

Complete Specification Published: 25 June, 1969.

© Crown Copyright 1969.

Index at acceptance:—H1 T(1F, 4, 9)

Int. Cl.:—H 01 f 27/36

COMPLETE SPECIFICATION

Coated Electrostatic Shields for Electrical Apparatus

We, GENERAL ELECTRIC COMPANY, of 1 River Road, Schenectady 12305, New York, United States of America; a corporation organised and existing under the laws of the State of New York, United States of America, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to electrostatic shields and more particularly to coated electrostatic shields for encapsulated electrical apparatus.

As is well known to those skilled in the electrical apparatus art, many types of electrical apparatus use electrostatic shields as a means of controlling both internal and external voltage stresses. Electrostatic shields are used in electrical apparatus in areas where there would otherwise be a considerable voltage stress in the air adjacent to high voltage surfaces, for example in transformers, the area between the high voltage coil surface and the magnetic core of the transformer. In general, electrostatic shields are in the form of conducting metal foil. These shields have been found to be very satisfactory for use in apparatus using various types of fluids as an insulating medium. However, in encapsulated electrical apparatus the interface between the conductive foil and the encapsulating material tends to open or crack due to differences in thermal expansion of the various materials. As is well known these openings or cracks cause voids which fail under electrical stress, usually through ionization. Many attempts have been made to match the coefficient of thermal expansion of various conductive shielding material with the various types of insulating encapsulating material.

It has recently been discovered that an external electrostatic shield for an encapsulated coil structure may be provided by use of a conductive coating. This conductive coating may be in the form of a resinous material which is filled with a metallic powder or graphite. The conductive coating may be applied to the encapsulated coil structure in any desired manner, such as by brushing, spraying or dipping. As will be understood, such conductive coating provides no problem of differential expansion since the coefficient of thermal expansion of the conducting coating may be made substantially equal to that of the encapsulating resin.

Therefore, it is one object of this invention to provide a conductive coated electrostatic shield for an encapsulated electrical apparatus.

A further object of this invention is to provide a coated electrostatic shield for encapsulated electrical apparatus, which shield is formed of a conductive coating that will not pull away from or crack at the interface with the encapsulating material.

A still further object of this invention is to provide an electrostatic shield for encapsulated electrical apparatus which may have any desired resistivity.

According to the present invention there is provided an electrical apparatus having a high voltage winding encapsulated in a cured resinous material, and which comprises an electrostatic shield on the exterior surface of the encapsulating resinous material formed by a conductive coating of cured resinous material having a filler of conductive material, the resinous material of the conductive coating having substantially the same coefficient of expansion as the encapsulating resinous material, said conductive coating being electrically connected to a grounded portion of the electrical apparatus.

The invention will be better understood from the following detailed description of a preferred embodiment thereof particularly when considered in connection with the accompanying drawings, in which:

FIGURE 1 is a perspective view partially in section of an encapsulated coil unit with the conductive coating shield of this invention applied thereto; and

FIGURE 2 is a cross sectional view of a mold for encapsulating a coil unit showing one method of applying the conductive coating of this invention.

The description of this invention will proceed with reference to the drawings, in which like numerals are used to indicate like parts throughout the various views thereof. However, it should be understood that while this invention will be described with reference to a particular type electrical apparatus, such description is for purposes of illustration only and is not to be considered as limiting the scope of this invention.

Referring now to FIGURE 1 of the drawing there is shown a transformer 10 comprising an encapsulated coil unit 12 with inserted core members 14 and 16, shown in phantom view as passing through opening 18 of the coil unit 12. As shown, coil unit 12 includes a primary or high voltage winding 20 and a secondary or low voltage winding 22. The high voltage leads 24 are preferably brought out through the side of the encapsulated unit, while the low voltage leads 26 are brought out to the top or bottom of the encapsulated unit. In the particular embodiment shown the high voltage winding 20 includes a plurality of turns of wire wound on a winding form 28. The winding form 28 is shown with a central spacer 30 to separate the top and bottom portions of the high voltage winding 20. Of course it will be understood that such spacer is not necessary in the winding form. However, it is utilized to reduce the stresses between the various layers of the high voltage winding 20. The low voltage winding 22 is shown as being comprised of a number of turns of wire wound about a winding form 32. As clearly shown in the Figure, between the various layers of the low voltage winding 22, the layer insulation 34 is placed to insulate the various layers of the low voltage winding from each other, in a manner well understood by those skilled in the art. Of course, as will be understood, the layer insulation could also be provided on the high voltage winding if desired.

In general, when a coil such as coil unit 12 including the high voltage winding 20 and low voltage winding 22 is encapsulated within a synthetic resinous material both the high voltage winding and the low voltage winding are completely surrounded and impregnated with the encapsulating material. However, it has been found that a number of problems arise, especially with reference to the high voltage winding, in that voids are formed within the high voltage winding which are not filled by the encapsulating material. These voids are air or gas filled spaces and, in general, lead to corona due to the high voltage stresses at these points in the high voltage windings. As is well known this corona may damage the insulation materials and cause objectionable radio noise. Further, it has been discovered that apparently where the high voltage windings and the encapsulating resin contact each other they also provide a source of corona. It has further been found that the development of voids in the encapsulated high voltage winding, as well as the development of corona due to the contact of the winding with the encapsulating material, can be avoided by impregnating the high voltage winding with a dielectric liquid, such as for example mineral oil used in transformers. Only a small amount of dielectric liquid is necessary, generally, an amount sufficient to provide a film about each of the wires of the high voltage winding. However, a brief discussion will be given of the construction of the winding with reference to FIGURE 1 of the drawing.

As shown in FIGURE 1, after the high voltage winding is wound about the winding form 28 the open portion of the winding form is sealed to prevent any of the encapsulating material from coming in contact with the wires of the high voltage winding. This is preferably done by utilizing a continuous film about the open portion of the winding form 28, the continuous film being indicated at 36. A continuous film of glass-reinforced polyester makes a good sealant for the high voltage winding. Obviously, other films, such as polyethylene, may be used, either as a film or a laminate with glass fibres or the like. The only requirement for the sealing material is that it be sufficiently flexible and impermeable to the encapsulating resin to prevent such resin from contacting the high voltage winding 20. As can be seen from FIGURE 1, the use of sealant 36 completely seals off the high voltage winding 20 from the encapsulating material, generally indicated at 38 in the drawing. As indicated, the high voltage winding formed on the winding form 28 and enclosed by the sealant 36 is thus sealed in a cavity 29 prior to encapsulation of the coil 12. Means are provided in the winding form 28 of the high voltage winding 20 to add oil to cavity 29. Such means are generally indicated as tubes 40 at opposite ends of the encapsulated unit 12. As will be understood after the windings 20 and 22 have been encapsulated in the encapsulant 38, one of tubes 40 may be connected to a vacuum pump, the other tube is connected to a dielectric liquid source and the dielectric liquid is forced into the cavity 29 while such cavity is being evacuated in a manner well understood by those skilled in the art. This provides an encapsulated coil unit 12 in which the corona problems of the high voltage winding are substantially eliminated.

However, as will be understood there is also a problem of the stresses developed from the high voltage winding 20 through the encapsulating material 38 to the grounded core 14 or 16 of the transformer 10. In order to eliminate this problem the shielding means of this

invention may be utilized. As can be seen from FIGURE 1 of the drawing, the external surface of encapsulating material 38 is provided with a conductive coating indicated at 42. The coating 42 is comprised of a resinous material which is filled with either a metallic powder or graphite. It is preferred that the resinous material forming the conductive coating 42 be the same type of resinuous material used to form the encapsulating material 38. As will be understood when using a resinous material for the conductive coating 42 the same as the encapsulating material 38 the coefficient of thermal expansion of both the conductive coating and the encapsulant resinous material will be substantially equal. Of course, as will be understood, other types of resinous material could be used. However, as stated, the preferred method is to utilize the same type of resinous material for the conductive coating as is used in encapsulating the coil unit 12.

In some applications for example where the transformer 10 will be exposed to severe atmospheric conditions, or where it may be buried in the earth, a corrosion resistant conductive coating is desired, completely covering the external surface adjacent the high voltage winding. In such a case the conductive coating will constitute a short circuited turn linking the main flux of the magnetic cores 14 and 16. Therefore its resistance must be sufficiently high to keep the I^2R losses to a negligible portion of the total excitation loss and sufficiently low to conduct static charges to ground and eliminate corona adjacent the external coil surface. A commercially available graphite-filled epoxy resin having a resistivity on the order of 30 to 300 ohms per square inch has been found suitable. As will be understood the resistance is generally measured between two parallel sides of a 1″ square surface. The resistivity of the coating will vary considerably, depending upon the size of the transformer, the geometry of the coated surfaces and the thickness and other characteristics of the coating. However, as long as the criteria of low total loss and satisfactory shielding are satisfied, then the conductive coating will be sufficient for use.

In other applications where the transformer will not be buried nor exposed to severe atmospheric conditions, a lower resistance conductive coating using metallic fillers may be utilized. Such coatings generally have a resistance of the order of 1 ohm per square inch. As will be understood these conductive coatings must be discontinuous or they will produce a sizeable short circuit current and cause excessive power losses. Utilizing such conductive coatings with very small resistivity at least one longitudinal area approximately 1/2″ wide is left uncoated. This is shown in FIGURE 1 as the band 44 about the coil unit 12. Where a two section core is used, as indicated at 14 and 16 in the drawing, it is desirable that two uncoated bands be used. This is shown in FIGURE 1 by uncoated band 44 near core 16 and uncoated band 46 at the opposite end of coil unit 12, near core 14. The bands 44 and 46 divide the shield into two separate units so that the conductive coatings does not form a closed loop linking the magnetic flux of either or both cores. Each of these units is grounded to the cores 14 and 16, as is indicated at 48. As will be understood, when the coating is provided either by brushing, spraying or dipping the bands 44 and 46 may be formed merely be means of a strip of masking tape placed about the coil unit 12 which may be removed after the surface has been coated.

As will be understood, the interior surface adjacent the low voltage winding of coil unit 12 is not provided with a conductive coating. There is no need for an electrostatic shield between the low voltage winding 22 and the core sections 14 and 16. In general, the low voltage winding will provide sufficient shielding from high voltage stresses in this region due to the high voltage winding 20. However, if both windings were of relatively high voltage so as to develop considerable voltage stress between the interior of the coil unit 12 and the cores 14 and 16, a conductive shield could be provided as a continuation of conductive coating 42.

Referring now to FIGURE 2 of the drawing, there is shown one preferred means of applying the electrostatic shielding to the exterior of an encapsulated coil unit. As shown in FIGURE 2 a mold 50 is provided for encapsulating the high voltage coil 20 and low voltage coil 22. As shown the mold unit 50 comprises a base member 52 which includes a central portion 54 and sides 56 forming in such base unit 52 a cavity 58 in which the high voltage winding 20 and low voltage winding 22 may be inserted. The high voltage winding 20 and low voltage winding 22 are mounted within the cavity 58 and held stationary therein and above the lower portion of the base by means of plastic mounting members 60. Members 60 will be generally of cured resinous material substantially the same as the material to be used for encapsulating the windings 20 and 22. A cover member 62 is provided closely fitting base member 52 and being bolted thereto by means of bolt 64. Openings are provided, such as for example openings 66 and 68, which may be used to fill cavity 58 with the encapsulating resinous material. As will be understood, normally one opening, such as for example 66, will be used to pump the resinous encapsulating material into cavity 58, while opening 68 will be utilized to evacuate cavity 58 to insure that the resinuous encapsulating material thoroughly fills all of the openings within the cavity 58. In accordance with the embodiment of this invention, prior to insertion of the windings 20

and 22 into cavity 58 a coating of conductive material utilizing a resinous material filled with either a metallic powder or graphite is sprayed about the sides of the cavity 58, except the center portion 54, as is indicated by the coating 70. The coating 70 will form in place on the sides of cavity 58 in the manner shown. When the encapsulating material is pumped into the cavity 58 and thoroughly fills such cavity 58 the coating 70 is transferred to the encapsulating resin and becomes a permanent part thereof. This method of applying the conductive coating more firmly secures the coating to the encapsulating resin and makes it less subject to removal by erosion or abrasion than coatings which are sprayed on the unit after it has been encapsulated. This also eliminates the necessity of providing a cure for the coating 70 after the encapsulating material has been cured. As will be understood, after the encapsulating material has thoroughly filled the cavity 58, the encapsulating material is cured. In curing such encapsulating material the coating 70, which becomes a permanent part of the encapsulating material will be cured together with the encapsulating material.

WHAT WE CLAIM IS:—

1. An electrial apparatus having a high voltage winding encapsulated in a cured resinous material, and comprising an electrostatic shield on the exterior surface of the encapsulating resinous material formed by a conductive coating of cured resinous material having a filler of conductive material, the resinous material of the conductive coating having substantially the same coefficient of expansion as the encapsulating resinous material, said conductive coating being electrically connected to a grounded portion of the electrical apparatus.

2. An electrical apparatus as claimed in claim 1, wherein said conductive coating completely covers the external surface of the encapsulating resin, and has a resistivity in the range of 30—300 ohms per square inch.

3. An electrical apparatus as claimed in claim 1, wherein said conductive coating is discontinuous about the external surface of the encapsulating resin, said conductive coating having a resistivity of approximately 1 ohm per square inch.

4. An electrical apparatus substantially as described with reference to the accompanying drawings.

POTTS, KERR & O'BRIEN.

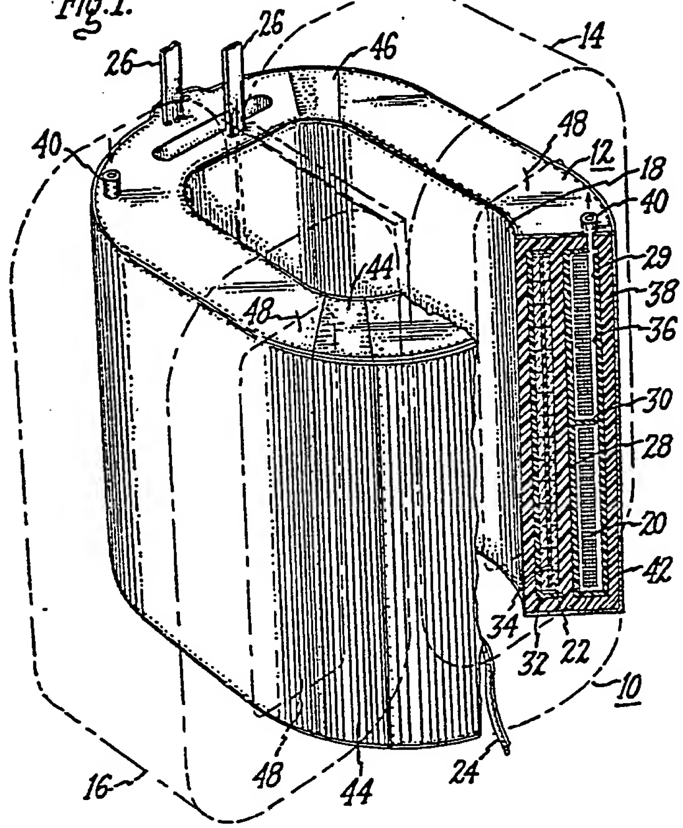
Printed for Her Majesty's Stationery Office by the Courier Press, Leamington Spa, 1969. Published by the Patent Office, 25 Southampton Buildings, London, W.C.2, from which copies may be obtained.

1156369 COMPLETE SPECIFICATION

2 SHEETS This drawing is a reproduction of the Original on a reduced scale

Sheet 1

Fig.1.



1156369 COMPLETE SPECIFICATION

2 SHEETS This drawing is a reproduction of the Original on a reduced scale

Sheet 2

Fig. 2.